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ELECTROLYSIS IN MAGNETIC FIELDS. (U)

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FINAL REPORT

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6. Author of Report: John Dash

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7. SUMMARY OF RESULTS: In addition to the results on the Leclanché cell ~~(see attachment)~~, significant progress has been made on the experimental studies of the influence of magnetic fields on the electrodeposition of copper and of chromium.

In the case of copper deposition, experiments have been performed with a long, glass cell, which was designed so that either the anode or the cathode could be placed in a magnetic field, the strength of which could be varied from zero to 13.4 kG. In this way it is possible to determine the effect of the magnetic field on each electrode process and to compare these results with results obtained when the entire cell was located in the field. The results of these experiments clearly show that it is not necessary to have the entire cell in a magnetic field in order to obtain the desirable results which ~~we have~~ were reported previously. When the anode is in a magnetic field, the uniformity of dissolution is enhanced. When the cathode is in a magnetic field, the uniformity of deposition is enhanced. The reduction in cell resistance appears to be caused solely by interaction of the magnetic field with the processes at the cathode.

The significance of these results is that the benefits of magnetic interaction with electrolysis can be obtained by incorporating into the electrolytic cell a means of applying a magnetic field at each electrode. If this were done, it may be unnecessary to circulate the electrolyte by mechanical means. This suggests that the idea

is practical because it is likely to be beneficial and economical for many electrolytic processes. It should be emphasized that electrolytic processes consume the largest fraction of the nation's electrical energy. The magnetic method should reduce energy requirements by 10% or more.

In the case of chromium deposition, nine-hour deposition experiments have been performed with two identical cells in series, one inside a magnetic field and the other outside. At a field strength of two kG, the cell in the magnetic field deposits 10% more chromium than the cell outside the magnetic field.

There are several possible mechanisms by which a magnetic field may enhance chromium deposition. One of these is by suppression of hydrogen evolution at the cathode. Our measurements have shown that a magnetic field of two kG suppresses hydrogen evolution by 10%. It is likely that significant differences in microstructures and mechanical properties result from this suppression, but this has not yet been proven.

From these investigations of three different electrolytic cells, it may be concluded that a magnetic field of moderate strength has significant beneficial effects on electrolytic processes in general. Much remains to be done to complete the characterization of these effects and to develop theory to explain them.

8. REPORTS PUBLISHED UNDER ARO SPONSORSHIP DURING THIS PERIOD:

a. W. Socha and J. Dash, "Influence of Magnetic Fields on the Energy Output of Leclanché Cells," J. Electrochem. Soc. 122, No. 8,

239C (1975) (abstract). An expanded abstract of this paper will be published in the volume of expanded abstracts of the Dallas, Texas meeting of the Electrochemical Society, October 5-10, 1975. A copy of the expanded abstract is attached.

9. PARTICIPATING SCIENTIFIC PERSONNEL:

a. W. Socha conducted the studies on the Leclanché cell, and he has used this research for his M.S. thesis, which is now in draft form.

b. H. Sepehri studied the influence of magnetic fields on the hydrogen - oxygen fuel cell. He resigned from our Ph.D. program before firm conclusions were possible on his research.

c. K. Housen, an undergraduate physics student, participated in the studies of chromium and copper deposition, in cooperation with other students who did not receive compensation from this grant.

INFLUENCE OF MAGNETIC FIELDS ON THE ENERGY OUTPUT OF LECLANCHÉ CELLS*

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Previous research has shown that the application of magnetic fields during electrolysis significantly improves the uniformity of anode and cathode processes, and, in some cases, reduces the electrical resistance of electrolytic cells (1). In order to explain these results, it is necessary to determine the effects of magnetic fields on (a) the bulk electrolyte and on (b) the charge transfer process at the electrodes. The Leclanché cell seemed attractive for these studies because the electrolyte is contained in a porous separator. Thus, the stirring of the electrolyte, which is observed in other cells during electrolysis in magnetic fields, should be minimal in the Leclanché cell.

Both Mallory type M910F and Union Carbide type 950 cells were used in these experiments. Cells were selected at random from commercial lots. Groups of six were connected in series and drained at constant temperature (0°C) in ice baths. One group of six cells in an ice bath was placed between the polepieces of a Varian V-4007 electromagnet, with the magnetic field direction parallel to the axes of the cylindrical cells. A similar group of six cells in an ice bath was placed outside the magnetic field. Each group of cells was connected in series with a constant resistance and in parallel with one channel of a Houston Instruments Model 2-3000 two-pen voltage-time recorder. In other experiments a Variflux Model 2 permanent magnet was used to apply a magnetic field normal to the axes of Union Carbide type 904 cells. These experiments were performed at room temperature, with a set of three cells in the magnetic field connected in series across a constant resistance and a similar set outside the field.

The energy output of the cells as a function of time was computed by manual integration according to,

$$(1) \quad E = \frac{1}{R}\int_0^t V^2\,dt \approx \frac{1}{R}\sum_i \bar{V}_i^2\,\Delta t_i \;,$$

where E = energy in joules,
R = constant resistance in ohms,
$\bar{V}_i$ = average voltage (in volts) across the constant resistance during the interval Δt_i ,
and Δt_i = time in seconds. The time intervals in the summation were each 60 seconds.

*This research was supported in part by U.S. Army Research-Durham under Grant No. 10960-MS.

The amount of charge passed was determined according to

$$(2) \quad Q = \sum_i Q_i \simeq \frac{1}{R} \sum_i \bar{V}_i \Delta t_i \ ,$$

where $\Delta t_i = 60$ sec. for each interval.

The results of these experiments are given in Table 1.

These results appear to establish conclusively that magnetic fields of a few kG reduce the internal resistance of Leclanché cells. It is likely that this effect is caused by reduction of chemical overpotential.

REFERENCE

1. J. Dash and W.W. King, J. Electrochem. Soc. 119, 51 (1972).

Table 1. Effect of Magnetic Fields on Leclanché Cell Output

	Magnetic Field Source					
	Electromagnet				Permanent Magnet	
	Magnetic Field (kG)				Magnetic Field (kG)	
	0	4.5	0	3.3	0	2.5
Type of Cells	M910F, size N	M910F, size N	950 size D	950 size D	904 size N	904 size N
No. of Experiments	1	1	5	5	6	6
No. Cells per Experiment	6	6	6	6	3	3
Temp., ^{o}C	0	0	0	0	-22	-22
Load per Cell, Ω	10	10	0.8 Av.	0.8 Av.	15 Av.	15 Av.
Time of Experiment, min.	600	600	1008 Av.	1008 Av.	1057 Av.	1057 Av.
Av. Energy Output per Cell, J	432	483	3530	4440	864	893
% Energy Increase due to Magnetic Field		11.8%		25.8%		3.4%
Total Charge Transferred, C	1009	1074				
Av. Voltage per Cell $\frac{J}{C}$	0.43	0.45				